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ABSTRACT

This study evaluated student preparation for a course in calculus for business, management, and social sciences as a prerequisite for success in probability theory. The study included a review of the literature, development of an assessment instrument and cut-off scores, and review and validation of the study criteria, the assessment instrument, and the cut-off scores. A 33-item questionnaire was administered during the 1997 spring semester to 20 students enrolled in a probability theory course at Orange Coast College (California). The students had completed a course in calculus for business, management, and social sciences. Results of the study indicated that although students showed weakness in four instructional objectives: implicit differentiation, calculus applications to probability, numerical techniques, and proof construction, they nevertheless were deemed adequately prepared for the probability theory course. Appended are calculus course instructional objectives, the proficiency criteria developed, a diagnostic student assessment examination in calculus, and a data/assessment results table. (Contains 54 references.) (JLS)

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# EVALUATION OF STUDENT PREPARATION IN CALCULUS FOR BUSINESS, MANAGEMENT, AND SOCIAL SCIENCES FOR PROBABILITY THEORY AT ORANGE COAST COLLEGE

Emergence of Higher Education in America

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A practicum report presented to Programs for Higher Education in partial fulfillment of the requirements for the degree of Doctor of Education

Nova Southeastern University

August, 1997

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Abstract of a practicum report presented to Nova Southeastern University in partial fulfillment of the requirements for the degree of Doctor of Education

EVALUATION OF STUDENT PREPARATION IN CALCULUS FOR BUSINESS, MANAGEMENT, AND SOCIAL SCIENCES FOR PROBABILITY THEORY AT ORANGE COAST COLLEGE

by

E. J. Arismendi-Pardi

August, 1997

The problem under investigation was that the Division of Mathematics and Sciences at Orange Coast College (OCC) expressed an interest in the evaluation of student preparation in Calculus for Business, Management, and Social Sciences (BMSS) in order to reduce the attrition rate while increasing success in Probability Theory. The purpose of this study was to evaluate student preparation in Calculus for BMSS as a prerequisite for success in Probability Theory based on student knowledge of calculus per the objectives of the course outline for Calculus for BMSS. There was one research question for this study: "To what extent are students in Calculus for BMSS prepared for Probability Theory based on their knowledge of calculus according to the course objectives of the Calculus for BMSS course?"

The procedures used for this evaluation study included: A review of the literature; establishment of a formative committee to assist in the development of an assessment instrument and cut-off scores; establishment of a summative committee to review,

discuss, and validate the criteria, instrument tool, and cut-off scores; the instrument tool was administered during the Spring Semester, 1997 to a total 20 students enrolled in the only section of Probability Theory that was being offered; the results obtained from the instrument tool were collected and analyzed by the researcher; and the summative committee validated the results to determine if there were any gaps between the criteria and the results obtained from the diagnostic instrument.

The results of this study suggested that students were adequately prepared for the Probability Theory course. The assessment results showed that students performed poorly in 4 out of 15 course instructional objective, namely, implicit differentiation, calculus applications to probability, numerical techniques, and construction of proofs which was an optional objective.

It was concluded that even though students showed weakness in four instructional objectives, they were prepared for the Probability Theory course. Finally it was recommended that the researcher disseminate results of the study to the Chair of the Calculus for BMSS course and to the faculty who regularly teach Calculus for BMSS.

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# Chapter 1

## INTRODUCTION

Orange Coast College is a public 2-year institution offering the Associate in Arts (A.A.) degree, certificates of completion, vocational education programs, community services, and college transfer programs for students whose majors require four or more years of college education. Orange Coast College (OCC) is one of three colleges in the Coast Community College District and was founded in 1947. The college is known as Southern California's leading transfer institution (Orange Coast College, 1996, p. 3).

### Nature of the Problem

One major component of baccalaureate degree programs in non-engineering quantitative fields such as business decision science, quantitative management and social sciences, economics, statistics, and mathematics is the completion of a two-course sequence in Calculus for Business, Management, and Social Sciences (BMSS), and a rigorous calculus-based Probability Theory course. According to Title 5 of the California Education Code, all courses are expected to adhere to the objectives of their approved course outlines (Orange Coast College, 1995, p. 16). Furthermore, "course outlines are legal documents carrying both course instruction information and state mandated information" (Orange Coast College, p. 16).

The Division of Mathematics and Sciences at OCC has expressed an interest in the evaluation of student preparation in Calculus for BMSS in order to reduce the attrition rate while increasing student success in Probability Theory (S. N. Johnson,

personal communication, March 20, 1997). Student preparation for Probability Theory can be evaluated according to student knowledge of calculus as suggested by the objectives of the approved course outline for the Calculus for BMSS course.

The results of the evaluation would assist the Division of Mathematics and Sciences, the Department of Mathematics, and the professors of Calculus for BMSS in their efforts to better prepare students for optimal learning and success in Probability Theory.

## Purpose of the Study

The purpose of this study was to evaluate student preparation in Calculus for BMSS as a prerequisite for success in Probability Theory based on student knowledge of calculus per the objectives of the course outline for Calculus for BMSS.

## Significance to the Institution

It is anticipated that this evaluation study will assist the faculty in the Department of Mathematics to identify course content areas that should be emphasized in the instruction of calculus to better prepare students for Probability Theory. It is also anticipated that the completion rate in Probability Theory will be likely to increase once the content areas for instruction in calculus are emphasized in the future delivery and instruction of the course. It is further anticipated that the college will be better able to use its resources in assisting students to transfer to 4-year institutions.

## Relationship to Seminar

This practicum was directly related to the Emergence of Higher Education in America seminar in that the issue of access to higher education via the community college is a current emerging issue in the State of California. According to a report from the California Intersegmental Committee (ICC) in conjunction with the Intersegmental Committee of the Academic Senates (ICAS), the California State Superintendent of Public Instruction, Delaine Eastin appointed a broad-based task force to make recommendations to improve the quality of mathematics performance in California in an effort to create opportunities for access to higher education for Californians and thus prepare them for the world of work (California Education Round Table, 1995, p. 1; California Education Round Table, 1997, p. 3).

In addition, according to the Report of the President's Commission on Higher Education for Democracy, 1947 (as cited in Goodchild and Wechsler, 1989, p. 645),

> educational leaders and institutions should take positive steps to overcome the conditions which at present obstruct free and equal access to educational opportunities [and create] . . . attitudes that will make education freely available to all.

Finally, Wattenbarger, Bryant, and Varcoe (1996) present their views on the future of higher education in the United States in terms of access to higher education as an emerging issue in that "a basic premise in American higher education has been that education is the basis for a sound democratic society" (p. 126).

## Relationship to the Concentration

The study was directly related to the mathematics education concentration because curriculum evaluation in relation to access to academic programs requiring the study of mathematics is an emerging topic of inquiry in the mathematics education literature. In addition, access to higher education in general and to academic programs requiring the study of mathematics in particular has been and continues to be an issue of debate and controversy among mathematics educators in the United States.

The study was also directly related to the mathematics education concentration because knowledge of abstract and rigorous mathematical ideas such as theorems and proofs are essential prerequisites for student success in virtually all branches of mathematics that provide access to academic programs requiring the study of mathematics (Schumacher, 1996, p. 5). Hence, there is an interrelationship between the nature of this practicum and the selected area of concentration.

## Research Question

There was one research questions for this study: "To what extent are students in Calculus for BMSS prepared for Probability Theory based on their knowledge of calculus according to the course objectives of the Calculus for BMSS course?"

## Definition of Terms

For the purposes of this practicum, the following terms needed clarification.

Algorithm. An algorithm is a particular procedure for solving a certain type of problem.

BMSS. BMSS is the emphasis of a mathematics course or courses of study with applications in business, management, and social sciences.

Business Decision Science. Unlike Business Administration, Business Decision Science is a specialized field of quantitative methods, operations research, or management science that deals with the rigorous applications of mathematics, probability, operations research, and statistical methodology to solve business, management, financial, and economic problems from a scientific point of view. The term Business Decision Science is also known as decision science, quantitative systems, or systems analysis.

Calculus. Calculus is a mathematics course of study that deals with change and motion.

Calculus for BMSS. Calculus for BMSS is a mathematics course of study that deals with change and motion as it relates to business, management, and social sciences.

Derivative. The derivative is the rate of change of a function with respect to its independent variable. The

derivative is sometimes called the differential coefficient of the function, or the derived function. The derivative of a function y = f(x) is defined by $\frac{dy}{dx} = \lim_{\Delta x \to 0} \frac{f(x + \Delta x) - f(x)}{\Delta x}$.

Integration. Integration is the converse of differentiation. If f'(x) is the differential coefficient of f(x), the problem of integration is, given f'(x), to find f(x); or given dy/dx, to find y. Integration is also know as anti-differentiation.

Mathematical Notation. Mathematical notation is referred to as the proper use and algebraic manipulation of symbols, constants, and variables in mathematical discourse or exposition.

Probability Theory. Probability theory is a specialized field of mathematics or branch of mathematics as well as a course of study of the likelihood of the occurrence or nonoccurrence of an event under uncertainty.

Proof. A mathematical proof is a procedure or technique that uses precise and logical arguments by which the validity of a mathematical generalization can be established.

Theorem. A theorem is a consequence based on assumptions called axioms or the generalization of a mathematical truth that is based on mathematical reasoning and logical arguments.

# Chapter 2

## REVIEW OF THE LITERATURE

A review of the literature on strategies to evaluate course objectives to strengthen instruction and student success provided the theoretical foundations for this problem solving practicum. The investigation of the literature provided a wealth of information concerning strategies used to evaluate the objectives of mathematics courses. This chapter presents (a) evaluation of course objectives to strengthen instruction and student success, and (b) evaluation of objectives of mathematics courses to strengthen instruction and student success.

### Evaluation of Course Objectives to Strengthen Instruction and Student Success

The purpose of evaluating course objectives to strengthen instruction and student success is "to take a look at what is taking place in the classroom [to determine] how well students' needs are being met" (Rogers, 1994, p. 329). Evaluation of student performance provides educators with formative information designed to formulate standards that will ultimately improve instruction and increase learning (Doig, 1994, p. 2). Schuman (1992, p. 3) states that "authentic evaluation of educational achievement directly measures actual performance in [a particular] subject area." Cohen (1995) points out that the intent of program or course evaluation is to make recommendations to thus improve and update an existing course or set of courses within a specific academic program (p. 56).

According to the Community College League of California (1997), curriculum evaluation permits educational practitioners to obtain adequate information to assess teaching and learning (p. 1). The Community College League of California (1997) also points out that curriculum evaluation is a tool used by educators in making decisions about college enrollment (p. 1). Curriculum evaluation also permits educational practitioners to identify the strengths and weaknesses of colleges in order to improve the educational quality of the institution (Community College League of California, p. 1).

McKeachie (1994) points out that "the ultimate criterion for evaluating [instruction] is student learning" (p. 313). In evaluating pedagogical effectiveness it is imperative that a group of teachers teaching the same subject be selected to determine a criteria for whether or not students have learned the objectives of a course (McKeachie, p. 316). One way to assess teaching effectiveness is to use test scores . . . in order to determine if the course objectives have been achieved (Kemp, Morrison, & Ross, p. 289). However, Rabinowitz (1996) points out that

> evaluation . . . relies fundamentally on human judgement. To be meaningful and useful to teachers, students, and other potential users . . ., judgements must be informed, consistent, and equitable. This means that student work must be evaluated against rigorous and well-defined expectations. Scoring guides, or rubrics, make explicit the expectations by which student work can be evaluated. (p. 31)

Several researchers have concluded that assessment plans designed for the purpose of instructional improvement must be faculty-driven and should be conducted by an instructional

specialist or curriculum coordinator with experience in using assessment to improve instruction and increase learning (Cizek, 1995, p. 248; Foley & Terrance, 1996, p. 1). Furthermore, assessment plans and evaluation of student academic performance should also be faculty-driven because teachers can recognize sources of misunderstanding and point them out in their teaching in an effort to improve instruction and increase learning in a given subject area (Stacey & MacGregor, 1997, p. 113). The point of view that evaluation of curriculum serves as a tool for the improvement of instruction and learning has been endorsed by the California State Legislature. According to the California Assessment Academic Achievement Act of 1995 (1995), evaluation "should be designed to assist in the improvement of teaching and learning in California public classrooms" (p. 90).

In evaluating student academic work, Wiley and Yoon (1995) recommend "performance assessments [designed to] engage students in activities that require them to integrate their knowledge with their problem-solving and communication skills, and to encourage students to think" (p. 355). Bergan (1997) concurs with Wiley and Yoon (1995). She believes that assessment of student academic performance should be rigorous (p. 2). Furthermore, performance based assessment of student work should require students to demonstrate what they know and are able to do (L. M. Smith, Kuhs, & Ryan, 1993, p. 7). Therefore, educators should be skeptical of standardized tests since they generally cover a very narrow range

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of subject matter, generally emphasize low-level thinking, and limit students' ability to focus on problem solving strategies (Senk, Beckmann, & Thompson, 1997, p. 188; Toom, 1993, p. 24).

According to Lacampagne (1993), "the majority of standardized tests . . . are still overly reliant on multiple choice items that measure low-level . . . skills" (p. 15). Kober (1991) points out that

> results [from] standardized tests must be viewed with some caution . . . because answers to multiple choice items have limited utility in assessing higher order skills, an over reliance on standardized tests can perpetuate an inappropriate focus on lower order skills. . . . Evaluation instruments that are closely aligned with the objectives of the curriculum are generally more useful for diagnosing instructional needs and modifying classroom instruction than standardized, norm-referencing tests. (p. 37)

It is important that assessment of student academic work not be limited by multiple-choice questions (California Assessment Academic Achievement Act of 1995, p. 90). Schuman (1992) agrees with the California Assessment Academic Achievement Act of 1995 (1995) and points out that "authentic evaluation will provide far more information than any multiple-choice test possibly could" (p. 4).

Pandey (1990, p. 2) proposes a 3-step strategic evaluation of academic performance that requires students to:

1. Formulate problems
2. Devise solutions
3. Interpret results

Collins (1993) discusses the importance of considering course goals and objectives when using tests to evaluate student performance (p. 43). In addition, evaluation of student

performance "are best scheduled so as not to coincide with examination periods, end-of-term administrative duties, or popular school events, all of which legitimately compete for student and staff time attention" (Campbell, Edgar, & Halsted, 1994, p. 163). It is also important for students to complete the necessary prerequisites for a particular subject area before conducting an evaluation of student academic performance (Vockell, 1993, p. 200).

Many authors have suggested a variety of ways by which educational practitioners may score the results obtained from evaluating student academic performance. One author suggests scoring results according to a 4-point scale indicating 1 = very, 2 = moderately, 3 = slightly, and 4 = not at all (Wiley & Yoon, p. 359). Dessart (1997) concurs with Wiley and Yoon (1995) in that he also suggests using a 4-point scale where 1 = outstanding, 2 = adequate, 3 = inadequate, and 4 = no opportunity to observe (p. 242). On the other hand, Pandey (1990, p. 3) suggests scoring questions wholistically on a 6-point scale while Thompson (1991) suggests a 4-point scale where 3 and 4 are designated as successful (p. 6). Another author recommends using either a 3-point descriptive scale such as "basic", "proficient", or "advanced"; or an ordinal scale such as "0-4" (Rabinowitz, p. 31). Researchers L. M. Smith, Kuhs, and Ryan (1993) concur with Rabinowitz (1996) and suggest using a 3-point descriptive scale such as 1 for inadequate, 2 for satisfactory, and 3 for exemplary

(p. 11). Finally, educational researchers Campbell, Edgar, and Halsted (1994) suggest using a positive (+), negative (-), or neutral (0) scale in evaluating student academic work (p. 163).

## Evaluation of Objectives of Mathematics Courses to Strengthen Instruction and Student Success

Edge and Friedberg (1984) note that the lack of mathematical preparation is one reason students do not successfully complete mathematics courses. According to probability theorist Scheaffer (1990), the study of probability theory provides a strong basis "for those who may go on to deeper studies in statistics, mathematics, engineering, or the physical and biological sciences, and, at the same time, provides a basis for practical decision making in the face of uncertainty" (p. 3). Furthermore, Probability Theory is a difficult subject that requires indepth knowledge of differential and integral calculus (Ash, 1993, p. 9; Kelly, 1994, p. 11). According to Culotta (1992), "[differential and integral] calculus has long been the gateway to careers in science and engineering, but too often that gate slams shut" (p. 225). Goldstein (1989) points out that

> mathematics is a cumulative subject in which each topic rests firmly on a foundation consisting of all preceding topics . . . Without any question, the greatest problem which students experience in . . . any mathematics course . . . is a shaky understanding of the prerequisite topics. (p. 2)

Furthermore, mathematics educators Hendel and Boccio (1995) support Goldstein's (1989) point of view in that they believe that "if a course is designed as a prerequisite for another, it

should not only contain the prerequisite topics; it should also contain discussions or problems similar in form and complexity to those that will be used in the later course" (p. 35).

In order to evaluate student understanding of prerequisite topics and whether or not learning has been achieved, it is important to develop an evaluation instrument to assess the objectives of a prerequisite course (Kemp, Morrison, & Ross, 1994, p. 9). Mathematics education researchers Vincent and Wilson (1996, p. 249) developed the following 8-step checklist as a criteria to assess whether or not students have learned the objectives of a mathematics course:

1. Understanding the features of the problem
2. Use of appropriate strategy to solve the problem
3. Implementation of appropriate strategy accurately and efficiently
4. Explanation of procedures using correct mathematical language and notation
5. Validation of conjectures through mathematically logical arguments
6. Clear explanations and justifications to mathematical problems
7. Use of a variety of mathematical representations
8. Description of a general solution when appropriate

According to Toom (1993), in mathematics, "knowhow" is the ability to solve problems which is much more important than the possession of facts (p. 24). In reference to Toom (1993), Evans (1991) points out that the ability to solve problems can be

developed through teaching and strengthened through practice because problem solving skills can be taught (p. 14). Furthermore, according to Statement on Competencies in Mathematics Expected of Entering College Students (1996),

> Problem solving is the essence of mathematics. Problem solving is not a collection of things to be learned; it can not be reduced to a set of procedures. Problem solving is taught by giving students appropriate experience in solving unfamiliar problems, by then engaging them in a discussion of their various attempts at solutions, and by reflecting on these processes. (p. 3)

In reference to evaluating the objectives of mathematics courses to strengthen instruction and improve student success, the Standards in Mathematics and English for California High School Graduates (1997) reports that (as cited in Statement on Competencies in Mathematics Expected of Entering College Students, 1996, p. 3)

> There is no best approach to teaching, not even an approach that is effective for all students, or for all instructors. One criterion that should be used in evaluating approaches to teaching mathematics is the extent to which they lead to the development in the student of the dispositions, concepts, and skills that are crucial to success. It should be remembered that in the mathematics classroom, time spent focused on mathematics is crucial. The activities and behaviors that can accompany the learning of mathematics must not become the goals in themselves--understanding mathematics is always the goal. (p. 8)

To evaluate student success in mathematics, P. C. Smith (1995) suggests the use of writing assignments as a possible component of the assessment instrument tool because writing stresses the importance of communication and emphasizes accurate analysis and interpretation of data (p. 50). Haver and Turbeville (1995) concur with P. C. Smith (1995) in that their research has indicated that oral and written communication are

important activities designed to actively engage students in doing mathematics (p. 46). On the other hand, Culotta (1992) points out that evaluation of student success in mathematics depends on student understanding of the subject matter from three perspectives: Algebraically, graphically, and numerically (p. 225). Moreover, research in mathematics education conducted by Casciotti and Beken (1996) suggests that "students seem to better appreciate the analysis [of a problem] after [algebraic, graphic, and numeric] experimentation (p. 13). According to Donnell (1996), experimentation will ultimately lead students to discover important mathematical generalizations (p. 18).

Posnick-Goodwin (1997) points out that evaluation assessment instrument tools can have a negative effect on instruction and learning in that she concludes that teachers may sometimes feel pressure to have students do well on tests which results in teaching to the test to thus meet certain standards for success (p. 11). In evaluating the objectives of mathematics courses to strengthen instruction and student success, Azzolino (1996) suggests (as cited in Kibler, 1970) using assessment instrument tools based on "Bloom's cognitive complexity categories: Evaluation, synthesis, analysis, application, comprehension, and knowledge" (p. 32). She further suggests that in evaluating learning objectives, students should be asked to discuss, explain, compare, and use information obtained from graphs

(Azzolino, p. 36). In other words, "[students] should think about mathematics, rather than just perform algorithms" (Azzolino, p. 36). Romberg (1992) concurs with Azzolino's (1996) research in that he concludes that

> the goal of school mathematics is to teach students to think, to make them comfortable with problem solving, to help them question and formulate hypotheses, investigate, and simply tinker with mathematics. In other words, the focus is turned inward to cognitive mechanisms. (p. 35)

The primary function of assessment and evaluation of the objectives of mathematics courses to improve instruction and increase learning is to assist students and educators to monitor the progress of the learning process (Haury, 1993, p. 2). Furthermore, "assessment [and evaluation] in this context . . . must measure specific learning outcomes . . . and should encompass . . . much more than standardized [multiple-choice] testing" (Haury, p. 2). Lewis (1996) points out that specific learning outcomes does not mean "encyclopedic", and that evaluation of learning objectives must not only be rigorous, but must also be measurable and inform students what they have accomplished (p. 62). From a mathematics assessment point of view, it is important to preview texts or other published instructional materials before selecting a particular assessment tool to evaluate the learning and instructional objectives of mathematics courses (Hendel & Boccio, 1995, p. 34). However, Cipra (1996) is opposed to this approach because of the increased number of reformed mathematics educational materials that have

"dumbed down" the subject by deemphasizing the technical mastery of integrals, derivatives, and by completely abandoning rigorous mathematical proofs of theorems (p. 902).

Brown (1996, p. 63) suggests the following strategy to evaluate instructional and learning objectives of mathematics courses in relation to student success:

1. Understanding of mathematical vocabulary
2. Use of conventional mathematical terminology in analyzing problems
3. Ability to interpret solutions to problems
4. Communicating the findings

However, J. P. Smith (1996) points out that "solving problems is a matter of recalling and applying the procedure appropriate for the given problem type. Because of the heavy demands on memory, success in mathematics may well depend on students' effort or innate ability" (p. 391). Vaille and Kushins (1993) concur with Brown's (1994) in that they conclude that one way to assess the instructional and learning objectives of mathematics courses is to evaluate the degree to which students communicate mathematical ideas effectively (p. 11). Mathematics educators should use performance-based and open-ended questions when evaluating student work because these types of questions place an emphasis on the process used to analyze and solve problems rather than focus on a single right answer (L. M. Smith, Kuhs, & Ryan, p. 14; Frye, 1991, p. 2). Furthermore, the purpose of evaluating the objectives of mathematics courses is to improve the teaching of mathematics while maintaining rigorous academic content (Brosnan

& Hartog, 1993, p. 1; Commission for the Establishment of Academic Content and Performance Standards, 1997, p. 5.; Frye, p. 3). In contrast, Manji (1995) does not agree with either L. M. Smith, Kuhs, and Ryan (1993) or Frye (1991) in that he believes that it is important to understand the concepts and rationale behind complicated mathematical equations, formulas, expressions, and functions (p. 20).

According to Wilcox and Zielinski (1997), evaluation is a powerful tool to help mathematics educators monitor the effectiveness of their own teaching, judge the usefulness of learning, and shape their ongoing instructional decisions (p. 223). From an assessment perspective, evaluation affords students the opportunity to engage in higher order thinking (Curcio & Artzt, 1996, p. 668). Moreover, in evaluating student performance, mathematics educational practitioners must take into consideration whether or not the context of the task presents adequate performance criteria by which students can judge the quality of response (Curcio & Artzt, p. 672). Stick (1997) points out that test items designed for the purpose of evaluating instruction and learning must include analytical approaches to problem solving, require understanding of abstract mathematical concepts, and allow students to demonstrate evidence of manipulation of mathematical procedures (p. 356).

Finally, mathematics assessment researchers Brosnan and Hartog (1993) point out that the goal of evaluating the objectives of mathematics courses to strengthen instruction and student success is to promote the development of mathematical

power for all students and to help bring all groups of students to high levels of performance in the mathematical sciences (pp. 1-2). Evaluation and assessment of academic standards play a pivotal role in the improvement of teaching, learning, and academic performance (Johnson, Farkas, & Bers, 1997, p. 39). Thus, "mathematics teachers should encourage students to develop their capability to discover mathematical relations embedded in any piece of information (Davidenko, 1997, p. 144).

## Summary

The literature revealed that the primary purpose of evaluating course objectives to strengthen instruction and student success is to determine how well the needs of the students are being met. The literature also suggested that the purpose of evaluating course objectives in relation to improving instruction and increasing learning is twofold. First, evaluation measures actual performance in a particular subject area. Second, evaluation serves as a vehicle in making recommendations to improve and update a specific course or set of courses within an academic program. In addition, curriculum evaluation allows educators to obtain information necessary to make decisions about college enrollment, and to identify the strengths and weaknesses of the college in an effort to improve the educational quality of academic programs.

One way to determine if the learning objectives of a course have been achieved is to analyze the result of test scores obtained from student assessments. The rationale behind this reasoning is that student learning is the ultimate criterion for

evaluating instruction. Evaluation is based on human judgement. Therefore, in evaluating student work, educators must ensure that the work be evaluated against well-defined objectives. The assessment plans for the evaluation of student work in an effort to improve instruction and increase learning must be faculty-driven and chaired by a specialist in curriculum evaluation. The reason for faculty-driven evaluations is that teachers can recognize difficulties during the teaching/learning processes and point them out in their teaching in an effort to improve instruction and increase learning. The literature also revealed that the California State Legislature fully endorses the evaluation of teaching and learning.

The evaluation of student academic work should encourage students to engage in activities that foster problem-solving skills by requiring students to demonstrate what they know and are able to do. However, educators should view standardized tests with caution because according to the literature, these assessment tools emphasize low-level thinking and analytical skills. The evaluation of student performance should be based on problem formulation, solution, and interpretation of results. However, it is important to consider course goals and objectives when evaluating student performance. It is also important to schedule student evaluation as not to interfere with other college activities that may legitimately compete with student and

staff attention. Furthermore, it is crucial for students to have completed the necessary prerequisites prior to being evaluated for a particular subject area.

Various authors suggested a variety of ways to assess the results obtained from student evaluation of academic performance. Some assessment researchers agreed that a 4-point scale is an adequate approach to determine whether or not students meet the learning objectives of a course. Other assessment researchers suggested using a 3-point descriptive scale while yet others favored either a 6-point wholistic scale or a descriptive scale using "+" for positive, "-" for negative, and "0" for neutral.

The review of the literature on evaluating the objectives of mathematics courses to strengthen instruction and student success revealed that the lack of mathematical preparation is one reason students do not successfully complete mathematics courses. The literature also pointed out that the study of calculus-based Probability Theory provides a strong basis for students who may go on to pursue academic programs that require mathematical rigor and sophistication. Since mathematics is a cumulative subject that rests on the foundation of prerequisite topics, courses designed as a prerequisite should contain discussions and problems similar in form and complexity to those that will be encountered by students in future and subsequent courses.

In order to evaluate student understanding of prerequisite topics, it is important to develop evaluation instrument tools that assess course objectives and prerequisites. One mathematics education researcher developed an 8-point checklist criteria to

determine whether or not students had learned the objectives of a particular mathematics course. This checklist features the following components (a) understanding of the problem, (b) problem strategy, (c) solution, (d) explanation of the solution using correct notation, (e) validation of results and explanations based on logical arguments, (f) justification, (g) use of mathematical representations, and (h) description of a generalized solution. In addition, several authors pointed out the importance of problem solving skills when evaluating student academic work. The literature also revealed that problem solving skills is the essence of mathematics since problem solving skills can be taught by giving students the opportunity to solve unfamiliar problems.

There is no best approach to teaching that is effective for all students or for all instructors. However, one criterion that should be used in evaluating student performance is to include activities that encourage students to develop concepts and skills that are crucial to understanding mathematics. Several researchers suggest the use of writing assignments as one component of the assessment instrument tool. The writing process emphasizes the importance of communication in relation to the interpretation and analysis of data. In addition, communication skills allow students to be engaged in doing mathematics.

Evaluation of student success in mathematics depends on student understanding of the subject matter from three perspectives: Algebraic, graphic, and numeric. Moreover, students seem to better appreciate the analysis of problems after

algebraic, graphic, and numeric experimentation with a given problem. On the other hand, evaluation of student academic work may have a negative effect on instruction and learning because teachers may feel pressure to teach to the test to thus meet certain academic expectations. However, assessment instrument tools should be based on Bloom's taxonomy to thus encourage students to explain concepts and draw conclusions from graphs. The goal of evaluating mathematics courses in relation to teaching and learning is for students to think about mathematics and to go beyond the application of algorithms to solve problems. In contrast, the function of evaluation in relation to improving mathematics instruction and increasing learning is to assist educators in monitoring the learning process.

The learning outcomes of the evaluation process should be rigorous and provide students with information about what they have accomplished. In selecting an assessment tool to evaluate student performance, one author suggested reviewing published educational products. However, the literature has also indicated some caution in selecting published assessment tools because current publication materials have deemphasized many of the technical aspects of mathematics. In evaluating the learning objectives of mathematics courses, one author proposes the use of a 4-step guide that comprises the understanding of mathematics, the use of conventional notation, the interpretation of solutions, and the ability to communicate the findings.

Success in mathematics depends on student effort or innate ability. One way to assess the instructional and learning objectives is to evaluate the degree to which students can communicate mathematical ideas effectively. Therefore, educators should use performance-based assessment tools that emphasize analysis of problems as opposed to focus on obtaining the correct answer. While the purpose of evaluating the objectives of mathematics courses is to improve teaching and learning, there is controversy surrounding the importance of mathematical rigor versus emphasis on understanding the concepts behind mathematical formulae. Furthermore, evaluation is a powerful tool to help mathematics educators monitor the effectiveness of their own teaching.

Evaluation affords students the opportunity to engage in higher order thinking. Also test items designed for the purpose of evaluating instruction and learning should include analytical approaches to problem solving as well as evidence of mathematical manipulation.

Finally, the evaluation of objectives of mathematics courses to strengthen teaching and increase learning should help students to perform at high mathematical levels. Evaluation in general plays an important role in the improvement of teaching and learning. Mathematics educators should encourage students to develop their abilities to discover the mathematical relations that may exist in any piece of information.

# Chapter 3

## METHODOLOGY AND PROCEDURES

### Procedures

The design used in this practicum report was the evaluation methodology. Six procedures were followed for the completion of this practicum report. First, a review of the literature was conducted. This review included strategies to evaluate course objectives to strengthen instruction and student success. The review also included strategies used to evaluate the objectives of mathematics courses to strengthen instruction and student success.

Second, a formative committee was established. In the context of the existing pre-established course instructional objectives for Calculus for BMSS (see Appendix A), the formative committee assisted with the development of the criteria (see Appendix B) to evaluate student preparation in Calculus for BMSS as a prerequisite to Probability Theory. The formative committee also assisted with the development of the instrument tool (see Appendix C) to assess student preparation in Calculus for BMSS at OCC. The instrument tool consisted of 33 questions associated with each of the 14 objectives and one additional question associated with an optional objective. Due to the nature of the subject matter, there were more questions related to certain specific objectives and fewer to other objectives. The questions were selected from a validated bank of questions developed by the author of the textbook (i.e., Barnett and Ziegler's Applied Calculus for Business, Economics, Life Sciences, and Social

Sciences, 5th Edition, published by Macmillan) and provided by the publisher for instructor use. In addition, the formative committee assisted with the establishment of a cut-off score that indicated that students successfully learned the content associated with the objectives. A complete listing of the members of the formative committee and their credentials, as well as how and why they were selected is included in Appendix D.

Third, a summative committee was established. The criteria, instrument tool, and cut-off scores set by the formative committee were submitted to the summative committee for their review, discussion, and validation. A complete listing of the members of the summative committee and their credentials, as well as how and why they were selected is included in Appendix E.

Fourth, the instrument tool was administered during the Spring Semester, 1997 to a total of 20 students enrolled in only one section of Probability Theory since the course is only offered once a year due to the nature of its mathematical rigor. The students enrolled in the Probability Theory course would have completed Calculus for BMSS taught by one of several professors of calculus at OCC or at another college.

Fifth, the results obtained from the instrument tool to assess student preparation in Calculus for BMSS at OCC were collected and analyzed by the researcher.

Sixth, the student performance results were presented to the summative committee for validation against the previously established formative criteria and cut-off score to determine if

there were any gaps between the criteria (i.e., the ideal state) and the results obtained from the diagnostic instrument to assess student preparation in Calculus for BMSS at OCC (i.e., the actual state).

## Assumptions

For this practicum, it was assumed that the formative committee had the knowledge to develop the criteria for the assessment of student preparation in Calculus for BMSS as a prerequisite to Probability Theory. It was also assumed that the summative committee's evaluation of the developed formative criteria was valid. It was further assumed that students who completed a calculus course at another college were comparable in mathematical ability to the students who completed Calculus for BMSS at OCC.

## Limitations

The results obtained in this study were limited in that the evaluation of student preparation in calculus as a prerequisite for Probability Theory was specific to mathematics, the Department of Mathematics, and to the college. This limitation may be a threat to the external validity of the study in that the results of the findings relate to community college students in general and to students at OCC in particular.

# Chapter 4

# RESULTS

## Findings From the Literature Review

The literature review provided expert information, guidelines, strategies, and examples for evaluating course objectives to strengthen instruction and student success. The literature also provided expert information on the particulars for evaluating the objectives of mathematics courses in relation to improving instruction and increasing learning. Over eighty sources were reviewed to determine the specific strategies and components that should be included in the evaluation of student preparation in Calculus for BMSS for Probability Theory at OCC. The literature review provided the theoretical foundations for conceptualizing and justifying the results of the research question, "To what extent are students in Calculus for BMSS prepared for Probability Theory based on their knowledge of calculus according to the course objectives of the Calculus for BMSS course?"

The investigation of the literature suggested that student evaluation of academic work should be based on actual performance of student ability in solving problems. Research on instrument tools to evaluate student academic performance indicated that students should be allowed the opportunity to demonstrate the process of analyzing, obtaining, and interpreting the results of a particular problem instead of focusing on obtaining a single correct answer. Several authors raised questions concerning the validity and confidence associated with multiple-choice

assessment tools. The literature indicated that standardized multiple-choice testing measured low-level thinking and problem solving skills.

The literature also indicated that evaluation of student preparation as a prerequisite for success in subsequent courses must be faculty-driven and measured against well-defined objectives. Many researchers suggested a variety of approaches and strategies to analyze the results obtained from evaluating student academic performance. Several authors suggested using a wholistic approach when analyzing student academic work. There were recommendations for using a 4-point descriptive scale while other authors advocated to the use of a 3-point scale, and yet other experts suggested the use of approaches such as the 6-point scale or the use of descriptive labels.

The investigation of the mathematics education literature pointed out that student mathematical preparation plays an important role in the successful completion of mathematics courses. For instance, knowledge of differential and integral calculus is essential for success in Probability Theory. In designing an assessment tool to evaluate student performance in mathematics, prerequisite courses to Probability Theory such as calculus should allow students to become familiar with problems that will be encountered in future or subsequent courses. One author suggested the use of a writing component when evaluating student academic performance while another author favored the use of questions that encourage students to think about algebraic, graphic, and numeric approaches to problem solving. The

mathematics education literature pointed out that evaluation of student academic performance in mathematics courses for the purpose of improving instruction and increasing learning should be based on Bloom's taxonomy. In other words, evaluation of student preparation should cause students to think about mathematics rather than perform algorithmic operations since the goal of mathematics is to investigate abstract mathematical ideas, concepts, definitions, axioms, and theorems.

One mathematics education researcher suggested the use of published assessment tools provided by textbook companies designed for student assessment of course objectives. However, the literature revealed some controversy surrounding the use of validated assessment tools published by textbook companies. The mathematics education literature suggested the use of performance-based testing when evaluating student preparation for a subsequent course.

Finally, information gleaned from the literature revealed that the purpose of evaluation is to improve instruction, and increase learning. From a mathematical point of view, evaluation is a tool to assist students in performing at higher cognitive and mathematical levels.

## Development of the Criteria to Evaluate Student Preparation in Calculus for BMSS as a Prerequisite to Probability Theory

The criteria to evaluate student preparation in Calculus for BMSS as a prerequisite to Probability Theory at OCC were extracted from the literature review and from discussions with

the members of the formative committee. The developed formative criteria (see Appendix B) in the context of the existing pre-established course instructional objectives for the Calculus for BMSS course (see Appendix A) was as follows:

1. Evidence of proficiency in College Algebra or Precalculus mathematics when analyzing or solving calculus problems.
2. Evidence of proficiency in differential calculus
    a. Chain, product, and quotient rules
    b. Calculation of limits
    c. Implicit differentiation
    d. Solve first and second order differential equations
    e. Partial differentiation
3. Evidence of proficiency in integral calculus
    a. U-substitution
    b. Integration by parts
    c. Improper integration
    d. Double integration
4. Evidence of proficiency in optimization problems
5. Analysis and solution to applied problems in BMSS
6. Applications of Calculus for BMSS in Probability Theory
7. Understanding and constructing mathematical proofs

The formative committee was called to a meeting and reached consensus after two revisions of the criteria for the evaluation of student preparation in Calculus for BMSS as a prerequisite to Probability Theory at OCC. The changes made by the formative committee after the first scheduled meeting suggested that

students should demonstrate proficiency in differential and integral calculus, and apply calculus techniques to solve problems in BMSS. The committee also suggested that students be evaluated on the various probability topics that are covered in the Calculus for BMSS course at OCC.

The committee further suggested that a writing component be included as a criteria to evaluate student preparation of Calculus for BMSS. The members of the formative committee unanimously agreed that the construction of mathematical proofs must be included in the criteria to evaluate student preparation in Calculus for BMSS as a prerequisite for the Probability Theory course. During the first scheduled meeting the committee also established the cut-off score to determine adequate preparation in Calculus for BMSS as a prerequisite for success in Probability Theory. The committee's recommendation was that a 60% score would be an indication of adequate preparation in Calculus for BMSS as a prerequisite to Probability Theory at OCC. The rationale behind the 60% cut-off score was that many of the topics covered in Calculus for BMSS are difficult. Therefore, some leniency was necessary because this 5-unit semester course is very demanding due to the wide range of topics that are covered in a short period of time. In addition, the committee agreed that in analyzing student responses, a wholistic 3-point

descriptive grading scale be used. The committee further agreed that the wholistic scale should range from one to three as follows:

1. A score of "1" meaning "no pass"
2. A score of "2" meaning "pass"
3. A score of "3" meaning "high pass"

The committee suggested that the process of demonstrating how to analyze or solve a problem is far more important than the answer to the problem. Therefore, in wholistically analyzing student responses the following criteria must be used:

1. Use of proper mathematical notation
2. Proper and adequate use of algebraic manipulations
3. Top-down or left-to-right approach in solving problems
4. Adequate interpretation of results

At the second scheduled meeting, the formative committee agreed not to include the writing component criteria as previously recommended during the discussions of the first scheduled meeting. The writing component criteria was therefore removed from the list of formative recommendations. The committee indicated that the analysis of writing samples was within the purview of the Department of English. One of the members of the committee indicated that in analyzing writing samples, it is important to look beyond just content or answering the question or questions from a mathematical perspective. The committee member indicated that the analysis of writing samples must include criteria items such as tone, grammar, and spelling. The committee member further stated that the analysis of writing

samples must be subject to other criteria items such as use of proper form and style as well as syntax. The committee unanimously agreed that a writing component not be included as a criteria to evaluate student preparation in Calculus for BMSS. The final recommendations made by the formative committee during the second scheduled meeting suggested that the 3-point wholistic scale use for evaluating student responses be changed to a 4-point descriptive scale according to the following criteria:

1. A score of "0" meaning "inadequate"
2. A score of "1" meaning "marginal"
3. A score of "2" meaning "proficient"
4. A score of "3" meaning "excellent"

The rationale behind the revised criteria was that the committee strongly agreed that a student who does not show adequate performance in a particular task should not be rewarded with a score of "1". In addition, the committee indicated that a score of "1" assigned to an unanswered response would cause misunderstanding and could be misinterpreted. The committee indicated that there needs to be a well defined criteria for analyzing student responses in an effort to properly and fairly evaluate student preparation in Calculus for BMSS as a prerequisite for success in Probability Theory.

Finally, at the second scheduled meeting, the committee also agreed that the cut-off scores be converted to the 4-point scale in order to provide better information to students about the their performance. The rationale behind the conversion of scores was to use the 0-3 descriptive scale to properly counsel students

who did not have the adequate calculus preparation for Probability Theory to a remediation program. In addition, the committee also indicated that the use of the 0-3 descriptive scale should not in any way be associated with the A-B-C-D-F grading scale. The formative committee proposed that the formula "scale = 3.0 x (points achieved)/(total possible points)" be used to convert the scores to a 4-point scale ranging from 0 to 3. The committee suggested that a score of 1.75 be used as the cut-off score to indicate adequate preparation in Calculus for BMSS. Hence, suggesting that the 60% score be changed to 58%.

The members of the formative committee also suggested that a the following criteria be used to determine and define adequate preparation in Calculus for BMSS as a prerequisite for success in Probability Theory:

1. Adequate preparation in the context of the existing pre-established course instructional objectives for the Calculus for BMSS course means a score of at least 1.75 on any 10 out of 15 course objectives.

2. Overall effectiveness of the Calculus for BMSS course for the Probability Theory course would mean that 40% of the students who took the instrument assessment tool would have earned an overall score of at least 1.75 on the assessment instrument.

3. Since some objectives may contain more questions on a specific topic than other objectives, then the score for that objective would be calculated as the arithmetic mean of the scores obtained on each question.

A complete listing of the members of the formative committee and their credentials, as well as how and why they were selected is included in Appendix D.

## Development of the Instrument to Assess Student Preparation in Calculus for BMSS as a Prerequisite to Probability Theory

In the context of the 14 pre-established course instructional objectives (see Appendix A), an instrument to assess student preparation in Calculus for BMSS as a prerequisite for Probability Theory was developed. The questions for the assessment instrument were selected from a validated bank of test questions developed by the author of the textbook (i.e., Barnett and Ziegler's Applied Calculus for Business, Economics, Life Sciences, and Social Sciences, 5th Edition, published by Macmillan) and provided by the publisher for instructor use. The instrument contained 33 questions associated with each of the 14 instructional objectives and one additional question associated with an optional objective in the Calculus for BMSS course.

The developed formative criteria for the instrument to assess student preparation in Calculus for BMSS as a prerequisite for Probability Theory (see Appendix C) was as follows:

1. Instrument assessment tool should be based on the 14 pre-established course instructional objectives.

2. Instrument assessment tool must include a theoretical question (e.g., a mathematical proof of a theorem) associated with an optional course instructional objective.

3. Use validated bank of test questions developed and published by the author of the textbook to create the assessment instrument tool.

4. Allow two hours and thirty minutes for students to complete the assessment.

5. Assessment results are to be collected and analyzed by the researcher.

6. Students may use a non-graphing calculator while completing the assessment.

7. Scratch paper should be provided by the researcher and collected by the researcher once students complete the assessment.

8. The researcher will provide the answer booklet where students are to show set up, analysis, and solutions to problems.

The formative committee was called to a meeting and reached consensus after one revision of the criteria for the development of the instrument to assess student preparation in Calculus for BMSS as a prerequisite for Probability Theory. During the first meeting the formative committee agreed to delete the eighth criterion item. The formative committee indicated that there is a likelihood that students would make errors while working on the assessment instrument since students have to go back and forth from the assessment tool to the answer booklet. Therefore, the committee recommended that the assessment tool have adequate spaces between each question. In addition, the committee recommended that only the work shown on the space provided between each problem on the assessment tool be analyzed. The

committee suggested that the instructions given in the assessment tool be changed from "use the examination notebook provided with this test to work each problem completely and to show all your work. You may use a non-graphing calculator" to "work each problem completely and show all your work on the space provided only. Any work shown on scratch paper will be discarded. You may use a non-graphing calculator." The committee also recommended that students be required to leave the answers to each problem in simplest form. Therefore, the following sentence was added to the instructions given in the assessment instrument "your answers must be expressed in simplest form."

A final recommendation by the formative committee was to change question number 17 from "$\int x^{-} \ln x \, dx$" to "$\int x \ln x \, dx$" because the objective of the question is to assess whether or not students are able to uses the method of integration by parts to evaluate an indefinite integral. The committee pointed out that in changing the problem students would not need to perform two iterations of the integral to obtain the answer since only one iteration is necessary to demonstrate competency in using the method of integration by parts. A copy of the assessment instrument tool is included in Appendix D.

Validation of Criteria, Assessment Instrument Tool, and Cut-Off Scores set by the Formative Committee

The summative committee reviewed, discussed, and validated the formative criteria, assessment instrument tool, and cut-off scores. The summative committee reached consensus after one revision of the criteria, assessment instrument, and cut-off

scores that were previously established by the formative committee. The members of the committee believed that the criteria, the assessment instrument, and cut-off scores previously established by the formative committee were reasonable, and therefore validated them. A complete listing of the members of the summative committee and their credentials, as well as how and why they were selected is included in Appendix E.

## Analysis of the Results Obtained From the Diagnostic Instrument to Assess Student Preparation in Calculus for BMSS at OCC

The results obtained from the diagnostic instrument to assess student preparation in Calculus for BMSS at OCC revealed that 80% (i.e., 16 out of 20) of the students met the overall criteria established by the 1.75 cut-off score. However, four out of the fifteen objectives revealed scores mean scores below 1.75. The objectives that did not meet the 1.75 cut-off scores were implicit differentiation, applications of calculus involving probability distributions, and the optional objective on the construction of mathematical proofs or arguments to show generalizations of theorems.

The results from the assessment also revealed that student scores ranged from 1.02 to 2.88. The scores for each of the fifteen objectives ranged from 1.10 to 2.96. The following information was also revealed:

1. All (100%) students met Objective 1
2. Eighteen (90%) students met Objectives 2, 6, and 11

3. Seventeen (85%) students met Objective 12
4. Sixteen (80%) students met Objective 5
5. Fifteen (75%) students met Objectives 3, 7, and 9
6. Fourteen (70%) met Objective 8
7. Thirteen (65%) students met objective 10
8. Eleven (55%) students met Objectives 14 and 15
9. Eight (40%) students met Objective 4
10. Seven (35%) students met objective 13

The results indicated that the Calculus for BMSS course provided an adequate preparation in the context of the existing pre-established course instructional objectives for the Probability Theory course since the mean score on 11 out of 15 course instructional objectives was above the 1.75 cut-off score criteria. In addition, Calculus for BMSS at OCC appears to be an effective course in preparing students for Probability Theory because 80% of the students performed above the 1.75 cut-off score on the instrument assessment tool.

The results of the instrument assessment tool showed an overall score of 68%, that is, a score of 2.03 on the 0-3 point scale. Finally, the results obtained from the diagnostic instrument to assess student preparation in Calculus for BMSS at OCC are illustrated in Appendix F.

## Validation of the Results Obtained From the Diagnostic Instrument to Assess Student Preparation in Calculus for BMSS at OCC

The final procedure in this study involved the work of a summative committee. The summative committee reviewed the performance results obtained from the assessment instrument tool and concluded that the assessment results table in this chapter accurately depicted the findings of the study. The summative committee validated that the findings of this evaluation study answered the research question, "To what extent are students in Calculus for BMSS prepared for Probability Theory based on their knowledge of calculus according to the course objectives of the Calculus for BMSS course?"

The results of the summative committee evaluation were highly supportive of the findings of the study, and the committee members unanimously agreed that the Calculus for BMSS course at OCC is an adequate preparation for the Probability Theory course. The committee members also agreed that students did not adequately perform on the questions associated with Objectives 4, 13, 14, and 15 (i.e., implicit differentiation, applications of calculus in Probability Theory, numerical techniques, and proofs of theorems). The summative committee was not, however, surprised by the overall student performance below the 1.75 cut-off score on Objectives 13, 14, 15. The committee indicated that the topics associated with Objectives 13, 14, and 15 are not usually covered thoroughly due to time constraints, and the fact that perhaps professors tend to rush material coverage during the

latter part of a course. The committee stated that poor performance on the Objective 15, the optional objective, is probably due to student lack of exposure on how to construct mathematical arguments based on mathematical definitions, axioms, lemmas, and theorems.

The summative committee believed that the cut-off scores and criteria established by the formative committee were reasonable and, therefore, validated it. The committee recommended that professors of Calculus for BMSS spend more time on the topic of implicit differentiation, and perhaps reduce the amount of time that would be spent on applications of calculus to Probability Theory, numerical techniques, and construction of proofs. The summative committee members also strongly expressed that they felt the evaluation would significantly assist the Department of Mathematics at OCC to improve its curriculum in an effort to increase student learning and maximize teaching effectiveness. Finally, the summative committee concluded that there were no significant gaps between the criteria (i.e., the ideal state) and the results obtained from the diagnostic instrument to assess student preparation in Calculus for BMSS at OCC (i.e., the actual state).

# Chapter 5

# DISCUSSION, CONCLUSIONS, IMPLICATIONS, AND RECOMMENDATIONS

## Discussion

This study was conducted to evaluate student preparation in Calculus for BMSS as a prerequisite for a rigorous 1-semester calculus-based course in Probability Theory. The evaluation results were intended to assist the Department of Mathematics at OCC in revising its Calculus for BMSS curriculum in an effort to improve student success in Probability Theory. The evaluation results were also intended to guide the Department of Mathematics at OCC in its efforts to improve the teaching and learning of mathematics.

This evaluation study was also conducted to provide evidence about whether or not students would be prepared to successfully complete the Probability Theory course at OCC based on their knowledge of calculus according to the course instructional objectives of the Calculus for BMSS course. An intense effort was made to draw upon a comprehensive list of references to complete an evaluation study that would be informative and useful to the Division of Mathematics and Sciences as well as the Department of Mathematics at OCC. The concern and motive that led to the evaluation study was that the Division of Mathematics and Sciences had a keen interest in the evaluation of student preparation in Calculus for BMSS in order to reduce the attrition rate while increasing student success in Probability Theory (S.

N. Johnson, personal communication, March 20, 1997). Furthermore, there was no evidence concerning student preparation in calculus as a prerequisite for Probability Theory.

The literature clearly showed that the ultimate criteria to evaluate student preparation for a subsequent course is student learning. The literature also suggested that evaluation of student preparation in mathematics should be based on performance assessment instruments that encourage students to think about mathematical ideas instead of focusing on a single correct answer. In addition, the literature further suggested that evaluation instruments should encourage students to find solutions to mathematical inquiries through processes that suggest and involve algebraic, numeric, geometric, and theoretical approaches to problem solving.

Finally, it is expected that the evaluation results of this study will assist professors of Calculus for BMSS at OCC to be more sensitive about what students actually need to know to thus succeed in Probability Theory as well as in other mathematically related courses in non-engineering quantitative fields such as of business decision science, quantitative management and social sciences, economics, statistics, operations research and mathematics.

## Conclusions

It was concluded that students who complete a Calculus for BMSS course at OCC are adequately prepared for Probability Theory. It was also concluded that students showed weaknesses in four course content instructional objectives, namely, implicit

differentiation, applications of calculus to problems involving probability distributions, application of numerical techniques to find to solutions to equations or to evaluate integrals, and construction of mathematical proofs.

The study answered the research question, "To what extent are students in Calculus for BMSS prepared for Probability Theory based on their knowledge of calculus according to the course objectives of the Calculus for BMSS course?" The evaluation assessment instrument tool and evaluation criteria were deemed appropriate and were valid for this evaluation study. The evaluation study provided data that indicated what was being done in order to prepare students for Probability Theory and what content areas per the instructional objectives needed improvement. Finally, evaluation of student preparation in mathematics as a prerequisite for a subsequent course should be used as a tool to improve teaching and maximize learning.

## Implications

The Division of Mathematics and Sciences, the Department of Mathematics as well as professors of mathematics at OCC now have supporting evidence to guide them in the improvement of the teaching of mathematics. Furthermore, the division, the department, and the faculty will be better able to serve transfer institutions by providing them with adequately prepared students in mathematics. Finally, the results of this study will be useful to the faculty of the Department of Mathematics in their efforts for planning and delivering Calculus for BMSS curriculum.

Calculus for BMSS curriculum would emphasized essential topics per the instructional course objectives in an effort to improve student understanding, preparation, and success in mathematics.

## Recommendations

It was recommended that the results of the evaluation study be presented by the researcher to the Department of Mathematics at the 7th Annual OCC Mathematics Department Conference on Saturday, October 4, 1997 in Carlsbad, California during the scheduled Curriculum Improvement Concerns Session. It was also recommended that the researcher draft a memorandum at the beginning of the Fall 1997 semester to the chair of the Calculus for BMSS course. The memorandum would contain the results of the evaluation study and a recommendation to disseminate to all the Calculus for BMSS instructors to place greater emphasis on implicit differentiation, applications of calculus involving probability distributions, application of numerical techniques to find solutions to equations or evaluate integrals, and construction of mathematical proofs.

Finally, it was recommended that other prerequisite courses such as precalculus mathematics be evaluated to determine if the needs of students and transfer institutions are being met. The researcher should be responsible for accomplishing this recommendation by no later than the Fall 1998 semester.

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# APPENDIXES

Appendix A

Calculus for Business, Management, and Social Sciences

Course Objectives at Orange Coast College

**COURSE INSTRUCTIONAL OBJECTIVES**

1. Find the derivatives of polynomials, logarithmic and exponential functions.
2. Apply the chain, product, and quotient rules to find f'(x) given f(x).
3. Calculate limits of rational, exponential, absolute valued functions by using algebraic techniques and L'Hôpital's rule.
4. Use implicit differentiation to find y'.
5. Evaluate definite (proper and improper) and indefinite integrals by u-substitution and by the method of integration by parts.
6. Evaluate double integrals.
7. Find the domain, range, and asymptotes of rational functions.
8. Solve differential equation.
9. Find partial derivatives.
10. Find the Taylor series expansion for logarithmic and exponential functions.
11. Use limits and derivatives to sketch rational, polynomial, exponential and logarithmic functions.
12. Application of the method of Lagrange Multipliers in optimization problems.

13. Apply calculus in applications involving probability distributions.

14. Apply numerical techniques to find solutions to equations, find areas under a curve, and evaluate integrals.

■ Construction of mathematical proofs or arguments to show generalizations of theorems.

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NOTE: ■ means that this objective is optional.

Appendix B

Formative Committee Criteria

The criteria developed by the formative committee is as follows:

1. Evidence of proficiency in College Algebra or Precalculus mathematics in analyzing or solving calculus problems.

2. Evidence of proficiency in differential calculus
   a. Chain, product, and quotient rules
   b. Calculation of limits
   c. Implicit differentiation
   d. First and second order differential equations
   e. Partial derivatives
      (1) Logarithmic functions
      (2) Exponential functions

3. Evidence of proficiency in integral calculus
   a. U-substitution
   b. Integration by parts
   c. Improper integration
   d. Multiple integration
      (1) Over rectangular regions
      (2) Over irregular regions

4. Evidence of proficiency in optimization problems

5. Analysis and solution to applied problems in BMSS

6. Applications of Calculus for BMSS in Probability Theory

7. Evidence of understanding and constructing mathematical proofs in Probability Theory.

8. Analysis of student responses to the questions on the assessment instrument tool must be based on the following:

a. Use of proper mathematical notation

b. Proper and adequate use of algebraic manipulations

c. Top-down or left-to-right approach to solving calculus problems

d. Evidence of adequate interpretation of results where applicable

9. Scoring the assessment instrument tool will be based on a 4-point descriptive scale ranging from 0 to 3 as follows:

a. A score of "0" meaning "inadequate"

b. A score of "1" meaning "marginal"

c. A score of "2" meaning "proficient"

d. A score of "3" meaning "excellent"

10. The total number of points obtained from the instrument assessment tool should be converted to the 0-3 point scale according to the formula defined by "scale = 3.00 x (points achieved)/(total possible points)"

11. Adequate preparation in Calculus for BMSS would mean a percentage score of 58% or a score of at least 1.75 on the assessment instrument.

12. Adequate preparation in Calculus for BMSS as a prerequisite for success in Probability Theory is defined as a mean score of at least 1.75 on any 10 out of 15 course objectives

13. Overall effectiveness of the Calculus for BMSS course for the Probability Theory course means that at least 40% of the students who took the assessment instrument tool would earn a score of at least 1.75 on the assessment instrument.

14. Since some objectives may contain more questions on a specific topic that other objectives, then the score for that objective is calculated as the arithmetic mean of the scores obtained on each question.

15. Instrument assessment tool should be based on the 14 course instructional objectives and must include a theoretical question related to the 15th objective (e.g., a mathematical proof)

16. Use validated bank of test questions developed and published by the author of the textbook to create the assessment instrument tool.

17. Allow two hours and thirty minutes for students to complete the assessment instrument tool.

18. Assessment results are to be collected and analyzed by the researcher.

19. Students may use a non-graphing calculator as an aid to completing the assessment instrument tool.

20. Scratch paper should be provided by the researcher and collected by the researcher once students complete the assessment instrument tool.

21. The assessment instrument tool should have ample spaces between problems to allow students to show all their work in effort to obtain answers to the questions.

Appendix C

Validated Diagnostic Exam to Assess Student Preparation in Calculus for Business, Management, and Social Sciences at Orange Coast College

**MATH 157 DIAGNOSTIC STUDENT ASSESSMENT EXAMINATION IN CALCULUS FOR BUSINESS, MANAGEMENT, AND SOCIAL SCIENCES**

**Name:**_____ **Date:**_____

**Instructor:**_____ **Current Course:**_____

Instructions: Use the examination notebook provided with this test to work each problem completely and write the answer clearly on the space provided if applicable. Otherwise write clearly and show your work in detail on this diagnostic exam. ***YOU MUST SIMPLIFY ALL ANSWERS.***

Find $f'(x)$ for $f(x)$ as given:

1.) $f(x) = 3x^4 - 2x^2 + 1$.

Answer:_____

2.) $f(x) = 2\ln x + 3e^x$.

Answer:_____

3.) $f(x) = e^{2x+3}$.

Answer:_____

4.) $f(x) = \ln(x + 7)$.

Answer: _____

5.) $f(x) = e^{2x+3}$.

Answer: _____

6.) $f(x) = \dfrac{3x^2 + 4}{\ln x + e^x}$.

Answer: _____

7.) $f(x) = (17\pi)^{1-2x^2}$.

Answer: _____

Evaluate each of the following limits if possible:

8.) $\lim_{x \to 3} \frac{2x - 3}{x + 5}$.

Answer: _____

9.) $\lim_{x \to \infty} \frac{2x^2 + 2}{7x^2 - 17}$.

Answer: _____

10.) $\lim_{x \to 7} \frac{\sqrt{x} - \sqrt{7}}{x - 7}$.

Answer: _____

11.) $\lim_{x \to 0} \frac{e^{3x} - 1700}{x}$.

Answer: _____

12.) $\lim_{x \to 0} \frac{|x|}{x}$.

Answer: _____

13.) Find $y'$ for $y - xy^2 + x^2 + 1 - 0$ by implicit differentiation.

Answer: _____

Find and/or evaluate the following definite/indefinite integrals:

14.) $\int_2^5 (2x - 3)\,dx$.

Answer: _____

15.) $\int (e^{2x} + x^{-1})\,dx$.

Answer: _____

16.) $\int_1^{\infty} \frac{dx}{\sqrt[3]{x}}$.

Answer: _____

17.) $\int x \ln x \, dx$.

Answer: _____

18.) $\int_0^1 \int_0^1 4xy \, dy \, dx$.

Answer: _____

19.) Let $f(x) \quad \frac{3x}{x + 2}$, find the domain and any vertical or horizontal asymptotes if they exist.

20.) Find the general solution for $y'' + 3y' + 2y = 0$.

Answer: _____

21.) Let $z = e^{x^3 + 2y}$ find $\frac{\partial z}{\partial y}, \frac{\partial z}{\partial x}, \frac{\partial^2 z}{\partial x^2}, \frac{\partial^2 z}{\partial x \partial y}$.

22.) Use the method of separation of variables to find the general solution for $y' = 3x^2y^2$.

Answer: _____

23.) Use the integrating factor method to find a particular solution for $y' + y = x; y(0) = 0$.

Answer: _____

24.) Find the Taylor Series at $x = 3$ for $f(x) = e^x$.

Answer: _____

25.) Sketch the graph of $f(x) = x^3 - 18x^2 + 81x$ by using the first and second derivative tests (i.e., the graphing strategy). Indicate the critical values as well as the inflection points and intervals where $f(x)\nearrow$, $f(x)\searrow$, $f(x)$ is concave up, and $f(x)$ concave down.

26.) If $f(x,y) = x + 3y$ and $g(x,y) = x^2 + y^2 - 10$, use the method of Lagrange Multipliers to find the critical values of $F(x,y,\lambda) = f(x,y) + \lambda g(x,y)$.

Answer: _____

27.) If the probability of a new employee in a fast-food chain still being with the company at the end of one year is 0.6, what is the probability that out of 8 newly hired people 5 will still be with the company after one year? What is the probability that at least seven employees will be with the company after one year?

Answer: _____

28.) Salespeople for a business machine company have an average annual sales of $200,000, with a standard deviation of $20,000. What percentage of the salespeople would be expected to make annual sales between $240,000 and $430,000?

Answer: _____

29.) If $X$ is an exponential random variable, and if $P(4 \leq X) = e^{-2}$, then find the probability density function.

Answer: _____

30.) A 200 room hotel in Fresno is filled to capacity every night at a rate of $40 per room. For each $1 increase in the nightly rate, 4 fewer rooms are rented. If each rented room costs $8 a day to service, how much should the management charge per room in order to maximize the gross profit? What is the maximum gross profit?

Answer: _____

31.) The percentage of restaurants that fail during the first year of operation follow a beta distribution with $\beta = 2$. What is the probability that over 80% of the restaurants will fail during the first year?

Answer: _____

32.) Use Simpson's rule to numerically evaluate $\int_1^3 \ln(x)\,dx$.

Answer: _____

33.) Prove that $f(x) \begin{cases} (\beta + 1)(\beta + 2)x^{\beta}(1 - x) & 0 \le x \le 1 \\ 0 & \textit{otherwise} \end{cases}$

satisfies the requirements of a probability density function.

**END OF DIAGNOSTIC TEST**

## Appendix D

### Names and Backgrounds of the Members of the Formative Committee

Kevin Shannon, M.A.T.

Kevin Shannon is a professor of mathematics and computer information systems at Orange Coast College with over twenty years of teaching experience. Professor Shannon has teaching expertise in Finite Mathematics which is a quantitative course required by many quantitative fields such as management science, operations research, economics, statistics, and management information systems. Professor Shannon was asked to participate on the formative committee for this practicum report because of his expertise in teaching mathematics courses required by programs in the quantitative sciences. Professor Shannon has extensive experience in curriculum development and evaluation.

Nicholas Contopoulos, M.S.

Professor Contopoulos has many years of teaching experience in mathematics, physics, and astronomy. He is currently a member of the Department of Astronomy at Orange Coast College and has extensive experience in curriculum evaluation. Professor Contopuolos has also taught Calculus for BMSS and other mathematics courses at other community colleges prior to his tenure at Orange Coast College. Professor Contopoulos was asked to served in the formative committee because of his experience in developing and evaluating curriculum in mathematics and astronomy.

Masood Zaidi, Ph.D.

Professor Zaidi currently teaches mathematics at Orange Coast College. He has over twenty years of experience as an educator in mathematics, physics, and electrical engineering. Professor Zaidi was also the former dean of the Department of Engineering at Northrop University. Professor Zaidi has extensive experience in curriculum development and evaluation in the fields of engineering, mathematics, and physics. Masood Zaidi has also conducted extensive research in systems analysis and engineering. Professor Zaidi was asked to serve as a member of the formative committee because of his extensive experience in education and in the private sector.

Douglas Smith, M.L.S.

Professor Doug Smith currently teaches English at Orange Coast College and has been at Orange Coast College for over twenty five years. Professor Smith has extensive experience in wholistic assessment evaluation. Doug Smith has also conducted evaluation studies of student performance in English composition. Professor Smith has served on many college committees related to student success. He was asked to participate as a member in the formative committee because of his experience in developing assessment instrument tools as well as experience in curriculum matters in relation to student success.

## Appendix E

Names and Backgrounds of the Members of the Summative Committee

Raghu P. Mathur, M.S.

Professor Mathur is currently the interim president of Irvine Valley College. Professor Mathur also served Irvine Valley College for many years as a professor of Chemistry as well as Chair/Division Dean of the school of Physical Sciences and technologies. He has thirty years of experience in the field of chemistry, chemistry education, educational administration, and management. Professor Mathur possesses valuable knowledge in curriculum evaluation matters. He has worked closely with the Chancellor of the Saddleback Community College District in numerous curriculum projects. In addition, Raghu Mathur was elected to serve as President of the Board of Trustees of the Saddleback Valley Unified School District for many years. He is also the Vice-chair of the State Commission on Educational Policy for California Community Colleges. Finally, Professor Mathur was asked to serve in the summative committee because of his expertise and experience in curriculum development and evaluation.

Fred Feldon, M.A.

Professor Fred Feldon is currently the Department Chair in the Department of Mathematics at Coastline Community College. He has also served at Coastline Community College as the mathematics curriculum specialist with responsibilities in developing and evaluating curriculum. Professor Feldon has made many curriculum changes at Coastline in his efforts to improve instruction,

increase student learning, and reduce attrition rates. Professor Feldon has taught Calculus for BMSS at Coastline Community College, Rancho Santiago College, Orange Coast College, and Golden West College for many years prior to his tenure at Coastline Community College. Professor Feldon was asked to served in the summative committee because of his extensive experience as a mathematics curriculum specialist.

Daniel G. Martínez, Ph.D.

Professor Martínez currently teaches mathematics and statistics at California State University, Long Beach (CSULB). He has over thirty years of experience in teaching graduate and undergraduate mathematics, probability and statistics courses. Dan Martínez has been member of the Department of Mathematics at at CSULB for the past thirty years. Professor Martínez has received the award of "Distinguished Professor" for his pedagogical, curriculum, and research contributions to mathematics. Professor Martínez has also been a statistical consultant to various large corporations in Southern California such as Rockwell International Space Division, Boeing Aircraft Company, the Rand Corporation, and the Aerospace Corporation. Professor Martínez was the former president of the Southern California Chapter of the American Statistical Association. Professor Martínez is an active member of the American Mathematical Society, the Mathematical Association of America, the American Statistical Association, Quality Control Society of America, and the Society of Hispanic Engineers and Scientists. Professor Martínez was asked to serve in the summative committee

because of his broad and diverse experience in curriculum development, evaluation, and implementation in the field of Probability Theory and Statistics. Finally, Professor Martínez has been a leader in preparing and training students for successful careers in the mathematical sciences.

Appendix F

Raw Data and Assessment Results Table

| | Objectives | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Student | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| 1 | 3.00 | 2.75 | 2.60 | 0.00 | 2.75 | 3.00 | 3.00 | 3.00 | 1.00 | 3.00 | 3.00 |
| 2 | 3.00 | 1.50 | 1.40 | 0.00 | 0.75 | 0.00 | 1.00 | 0.00 | 0.00 | 0.00 | 2.00 |
| 3 | 3.00 | 2.25 | 1.40 | 0.00 | 2.75 | 3.00 | 1.00 | 1.33 | 2.00 | 3.00 | 1.00 |
| 4 | 3.00 | 2.75 | 2.40 | 2.00 | 0.25 | 3.00 | 3.00 | 2.00 | 2.00 | 3.00 | 3.00 |
| 5 | 2.33 | 2.50 | 1.20 | 0.00 | 1.50 | 3.00 | 3.00 | 3.00 | 0.00 | 3.00 | 2.00 |
| 6 | 3.00 | 2.25 | 1.80 | 0.00 | 2.75 | 3.00 | 2.00 | 2.67 | 3.00 | 1.00 | 3.00 |
| 7 | 3.00 | 2.25 | 2.60 | 0.00 | 2.00 | 3.00 | 3.00 | 1.00 | 2.00 | 0.00 | 1.00 |
| 8 | 3.00 | 2.50 | 2.40 | 2.00 | 3.00 | 3.00 | 3.00 | 2.00 | 1.00 | 1.00 | 2.00 |
| 9 | 3.00 | 2.75 | 2.80 | 2.00 | 2.25 | 3.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 |
| 10 | 3.00 | 2.25 | 2.00 | 2.00 | 2.00 | 3.00 | 3.00 | 2.00 | 2.00 | 1.00 | 2.00 |
| 11 | 3.00 | 2.00 | 2.00 | 1.00 | 2.50 | 3.00 | 2.00 | 2.00 | 2.00 | 3.00 | 2.00 |
| 12 | 3.00 | 3.00 | 2.60 | 1.00 | 2.50 | 3.00 | 3.00 | 2.33 | 3.00 | 3.00 | 3.00 |

(table continues)

| | Objectives | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Student | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| 13 | 3.00 | 1.25 | 2.60 | 3.00 | 2.00 | 2.00 | 2.00 | 1.33 | 2.00 | 0.00 | 2.00 |
| 14 | 3.00 | 2.00 | 2.60 | 3.00 | 2.50 | 3.00 | 3.00 | 3.00 | 2.00 | 2.00 | 3.00 |
| 15 | 3.00 | 2.25 | 0.60 | 0.00 | 1.50 | 3.00 | 1.00 | 1.67 | 2.00 | 3.00 | 3.00 |
| 16 | 3.00 | 3.00 | 2.60 | 3.00 | 3.00 | 3.00 | 3.00 | 3.00 | 3.00 | 3.00 | 3.00 |
| 17 | 3.00 | 2.25 | 1.40 | 0.00 | 2.00 | 0.00 | 3.00 | 2.33 | 3.00 | 0.00 | 3.00 |
| 18 | 3.00 | 2.25 | 2.40 | 1.00 | 2.25 | 3.00 | 1.00 | 2.33 | 1.00 | 3.00 | 2.00 |
| 19 | 3.00 | 2.00 | 3.00 | 2.00 | 2.50 | 3.00 | 3.00 | 2.66 | 2.00 | 2.00 | 2.00 |
| 20 | 3.00 | 1.75 | 1.80 | 0.00 | 2.00 | 2.00 | 1.00 | 1.66 | 2.00 | 3.00 | 2.00 |
| Mean | 2.96 | 2.27 | 2.11 | 1.10 | 2.13 | 2.60 | 2.30 | 2.06 | 1.85 | 1.95 | 2.10 |

Objectives

| Student | 12 | 13 | 14 | 15 | Score (%) | Mean |
|---|---|---|---|---|---|---|
| 1 | 3.00 | 2.60 | 3.00 | 3.00 | 88% | 2.64 |
| 2 | 0.00 | 1.20 | 0.00 | 0.00 | 34% | 1.02 |
| 3 | 3.00 | 1.60 | 1.00 | 1.00 | 63% | 1.89 |
| 4 | 2.00 | 1.80 | 1.00 | 1.00 | 67% | 2.01 |
| 5 | 2.00 | 1.20 | 1.00 | 1.00 | 61% | 1.83 |
| 6 | 2.00 | 1.80 | 2.00 | 2.00 | 74% | 2.22 |
| 7 | 2.00 | 1.80 | 2.00 | 2.00 | 67% | 2.01 |
| 8 | 2.00 | 1.60 | 1.00 | 1.00 | 72% | 2.16 |
| 9 | 2.00 | 0.60 | 2.00 | 2.00 | 72% | 2.16 |
| 10 | 2.00 | 1.60 | 2.00 | 2.00 | 69% | 2.07 |
| 11 | 2.00 | 1.20 | 1.00 | 1.00 | 65% | 1.95 |
| 12 | 3.00 | 2.80 | 3.00 | 3.00 | 87% | 2.61 |
| 13 | 0.00 | 0.20 | 0.00 | 0.00 | 50% | 1.50 |
| 14 | 3.00 | 1.20 | 2.00 | 2.00 | 77% | 2.31 |
| 15 | 3.00 | 1.40 | 0.00 | 0.00 | 54% | 1.62 |
| 16 | 3.00 | 2.80 | 3.00 | 3.00 | 96% | 2.88 |
| 17 | 2.00 | 2.00 | 1.00 | 1.00 | 62% | 1.86 |
| 18 | 3.00 | 1.20 | 2.00 | 2.00 | 71% | 2.13 |
| 19 | 1.00 | 1.20 | 2.00 | 2.00 | 74% | 2.22 |
| 20 | 2.00 | 1.00 | 2.00 | 2.00 | 54% | 1.62 |
| Mean | 2.10 | 1.54 | 1.55 | 1.55 | 68% | 2.03 |